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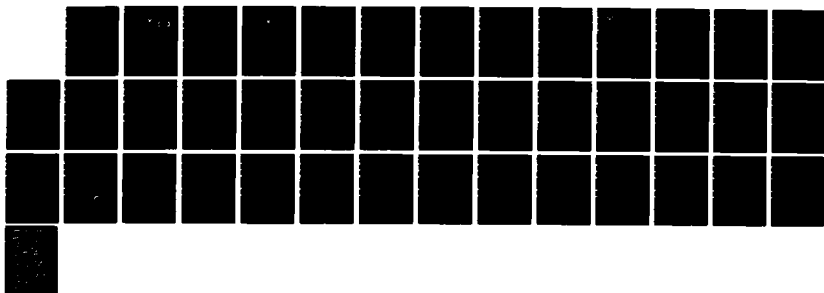
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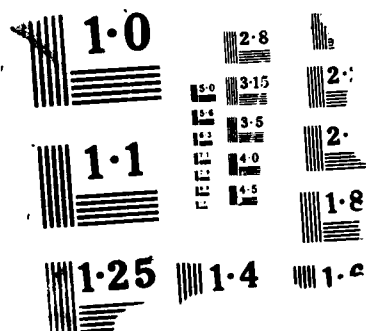
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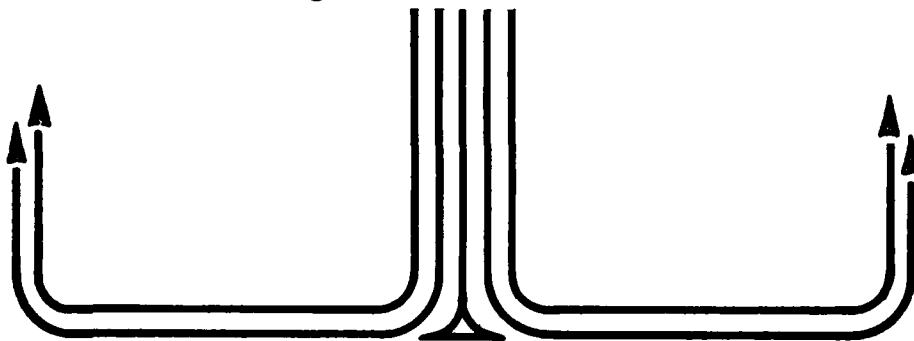
STUDENT REPORT

ADEQUACY OF GUIDANCE TO CONDUCT INITIAL OPERATIONAL SUITABILITY TEST AND EVALUATION OF INTERCONTINENTAL BALLISTIC MISSILES (ICBMs)

MAJOR STEPHEN C. POPP

88-2150

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REPORT NUMBER 88-2150

TITLE ADEQUACY OF GUIDANCE TO CONDUCT INITIAL OPERATIONAL
SUITABILITY TEST AND EVALUATION OF INTERCONTINENTAL
BALLISTIC MISSILES (ICBMs)

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requirements for graduation.

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PREFACE

Operational test and evaluation is not a new concept for the Air Force. Department of Defense, Air Force, and Air Force Operational Test and Evaluation Center (AFOTEC) regulations contain guidance to plan and conduct test and evaluation programs. However, the Peacekeeper ICBM is the first land based missile to undergo formal initial operational test and evaluation by AFOTEC. With no precedence, the planners of the Peacekeeper test program used the available guidance to develop test objectives, supporting tests, and methods to evaluate test results. This paper examines that guidance and its application in the Peacekeeper program to determine if it was and is adequate for land based ICBM operational test programs. With two new land based ICBM programs, Peacekeeper Rail Garrison and Small ICBM, now in the planning stages, the question of adequacy is particularly relevant. The paper limits its examination to only operational suitability.

The author wishes to thank his advisor, Major Larry Pulcher, for his patience and advice. Also, a special thanks to Lieutenant Colonel Doug Martin for sponsoring the project and Captains Mike Swingley and Pat McNamara for supplying data.



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—ABOUT THE AUTHOR—

Major Stephen C. Popp has 13 years experience as a missile maintenance officer. Assignments have included operational wing level, Headquarters Strategic Air Command, and most recently with the Air Force Operational Test and Evaluation Center's ICBM Test Team. Major Popp was Chief of the Availability Division, responsible for the reliability and maintainability evaluation of the PeaceKeeper weapon system. Major Popp has a Bachelor of Arts in Secondary Education from the University of Kentucky, a Master of Education in Guidance and Counseling from Wichita State University, and a Master of Science in Logistics Management from the Air Force Institute of Technology. Major Popp has completed Squadron Officers School in residence and Air Command and Staff College (ACSC) by correspondence. He is currently a student in the resident ACSC program.

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REPORT NUMBER 88-2150

AUTHOR(S) MAJOR STEPHEN C. POPP, USAF

TITLE ADEQUACY OF GUIDANCE TO CONDUCT INITIAL OPERATIONAL
SUITABILITY TEST AND EVALUATION OF INTERCONTINENTAL
BALLISTIC MISSILES (ICBMs)

I. Purpose: To determine if adequate guidance exists to develop test objectives, supporting tests, and evaluation methodologies for initial operational suitability test and evaluation of land-based ICBMs.

II. Problem: Operational test and evaluation is not a new concept for the Air Force; however, the majority of the test programs and guidance written to conduct test programs is oriented to aircraft and aircraft systems. While the Peacekeeper in Minuteman Silos program is drawing to a close, two new programs are in the planning phase: Peacekeeper Rail Garrison and the Small ICBM. Operational suitability objectives, supporting tests, and evaluation methodologies are required to support these programs. Therefore, a determination of the adequacy of guidance provided to develop test objectives, supporting tests, and evaluation methodologies for initial operational suitability test and evaluation of land-based ICBMs must be made.

III. Data: Guidance and direction to conduct operational suitability test and evaluation comes from Department of Defense and Air Force

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regulations. Direction to develop test objectives, supporting tests, and evaluation methodologies is described in AFR 55-43, Management of Operational Test and Evaluation, with more detailed guidance being provided in AFOTEC regulations and pamphlets. The process to develop test objectives is an analytical process where test objectives flow from the critical operational issues. Tests to support the suitability test objectives are developed from measures of effectiveness (MOE) which are quantitative measures of the objectives. Evaluation methodologies are the means to interpret test results. The examples and procedures given in the guidance are from aircraft or aircraft munitions test and evaluation programs. AFOTEC Pamphlet 400-1, Logistics Assessment provides specific guidance in appendices for various systems undergoing evaluation, but does not have an appendix for land-based ICBMs. The Peacekeeper in Minuteman Silos test program developed classic suitability test objectives of availability, logistics reliability, maintainability, and logistics supportability, but failed to develop suitability MOEs to support the objectives. The majority of the tests developed supported the maintainability objective. Some tests, which actually supported an objective, were not shown as supporting all related objectives. Evaluation methodologies used in the PIMS program were those suggested by the guidance with two notable exceptions: modeling and simulation, and reliability and maintainability growth techniques.

IV. Conclusions: The guidance to conduct operational suitability test and evaluation of land-based ICBMs has some shortcomings. The failure to address development of MOEs for ICBMs as separate and distinct from aircraft and aircraft systems may have contributed to the absence of suitability MOEs in the PIMS test program. There is also a lack of emphasis in the current guidance on development of tests to support suitability objectives. The guidance emphasizes test development for mission effectiveness tests, but does not give the same emphasis for suitability. Detailed descriptions of evaluation methodologies for various systems are provided in AFOTEC Pamphlet 400-1, in separate appendices, but no appendix exists for land-based ICBMs. This may have contributed to the PIMS program not using some of the suggested methodologies. However, the PIMS program test planners failed to utilize the guidance available.

V. Recommendations: The guidance to develop MOEs should recognize the differences between ICBMs and aircraft and include procedures to develop MOEs using terms relevant to ICBMs. An equal emphasis on suitability tests to support suitability test objectives is needed in the guidance. The current guidance to use simulation and modeling requires too much subjective analysis and not enough on actual system performance. An appendix should be added to AFOTEC Pamphlet 400-1 for land-based ICBMs addressing evaluation methodologies unique to these weapon systems. A new Air Force Pamphlet, AFP 57-9, Defining Logistics Requirements in Statements of Operational Need provides an example for other guidance to follow. This regulation provides guidance separate from aircraft and munitions, with terms relevant to ICBMs.

Chapter One

INTRODUCTION

BACKGROUND

The PeaceKeeper (MX) Intercontinental Ballistic Missile (ICBM) is the first new ICBM in over twenty years and the first to be formally tested by the Air Force Operational Test and Evaluation Center (AFOTEC). In April of 1983 a final decision was made to deploy the PeaceKeeper in existing Minuteman silos at Francis E. Warren AFB, Wyoming (3:1-2). Following this decision, plans for testing the system in this deployment mode were developed. It was also decided the test program would be conducted jointly, with initial operational testing integrated into the developmental test and evaluation (DT&E) program. AFOTEC had responsibility for conducting the initial operational test and evaluation (IOT&E) (3:--).

"The purpose of the PeaceKeeper OT&E program is to estimate the operational effectiveness and suitability of the weapon system in its intended operational environment" (3:1-3). The task for Headquarters AFOTEC and the AFOTEC test team was to develop test objectives, supporting tests and the methodologies to measure the performance of the weapon system in its intended operational environment. Since no previous land based ICBM IOT&E program had been conducted there was no precedent to follow. Department of Defense, Air Force, and AFOTEC regulations provided the guidance to develop objectives, tests, and methodologies. Additionally, the supporting tests had to be integrated into the existing DT&E program. The objectives and tests also had to consider the intended environment; a new airframe in an existing Minuteman silo. Other considerations for IOT&E test objectives and tests are the destructive nature of ICBM testing, the extensive silo support equipment, continuous run requirement, and differences between test facilities and operational sites. From the information available, the AFOTEC test team developed the PeaceKeeper Operational Test and Evaluation Plan describing the test objectives, supporting tests, and methodologies for the test program.

It is the opinion of this author that despite the existence of regulations and guidance to conduct OT&E, there does not exist adequate guidance addressing land-based ICBMs. The existing guidance is oriented towards aircraft and aircraft systems or munitions used by aircraft. While this lack of guidance affects both operational effectiveness and

suitability, this paper will examine the operational suitability issue only.

PROBLEM STATEMENT

Operational test and evaluation is not a new concept for the Air Force. However, the majority of the test programs and guidance to conduct test programs is oriented to aircraft and aircraft systems. The Peacekeeper test team has completed 17 of the scheduled 20 flight tests and submitted an interim test report. Test objectives, tests, and methodologies were developed to support the test program. As the Peacekeeper program draws to a close it is not the end of initial operational test and evaluation of ICBM systems. Two additional programs are in the test planning phase; Peacekeeper Rail Garrison and Small ICBM. Operational suitability test objectives, supporting tests and methodologies are required to support these programs. Therefore, a determination of the adequacy of guidance provided to develop test objectives, supporting tests, and evaluation methodologies for initial operational suitability test and evaluation of land based ICBMs must be made. Should deficiencies be noted recommendations for improved guidance must be identified. The research objectives for this paper are presented in Table 1-1.

LIMITATIONS

Operational test and evaluation is a very broad concept covering the entire life of a system. It is concerned with the operational mission effectiveness and operational suitability of a system. This paper will confine itself to only initial operational test and evaluation and further limited to operational suitability test and evaluation. The paper will confine itself to only the Peacekeeper in Minuteman Silos (PIMS) test program and will not consider previous Peacekeeper basing modes.

- | | |
|--------------|--|
| Objective 1: | To investigate Department of Defense and Air Force guidance for initial operational suitability test and evaluation. |
| Objective 2: | To investigate suitability test objectives and supporting tests used in the Peacekeeper in Minuteman Silos (PIMS) test program. |
| Objective 3: | To investigate methodologies used in the initial operational suitability test and evaluation of the PIMS test program. |
| Objective 4: | To compare Air Force and DOD guidance to the PIMS test program. |
| Objective 5: | To develop recommendations for additional guidance on operational suitability test objectives, supporting tests, and evaluation methodologies for future ICBM test programs. |

Table 1. Research Objectives.

Chapter Two

CURRENT GUIDANCE ON SUITABILITY TEST AND EVALUATION

The purpose of this section is to present the existing guidance on conducting operational suitability test and evaluation. First, the requirement for conducting operational suitability test and evaluation is presented, followed by the current guidance on how to develop suitability test objectives. The current guidance on how to develop actual tests to support the test objectives is explored, concluding with guidance on how to develop methodologies to evaluate test results. The findings in this section provide the basis to compare the findings in Objectives Two and Three, draw conclusions in Objective Four, and make recommendations in Objective Five as outlined in Chapter One.

REQUIREMENT FOR OT&E

Operational Test and Evaluation is directed by Department of Defense Directive 5000.3, Test and Evaluation and Air Force Regulation 80-14, Test and Evaluation. These Directives state:

Their [test and evaluation] primary purposes are: to identify, assess, and reduce the acquisition risks; to evaluate operational effectiveness and operational suitability; to identify any deficiencies in the system; and to ensure that only operationally effective and suitable, supportable system are delivered to the operating forces (9:2).

A further objective of Air Force operational test and evaluation is to "Evaluate . . . the operational suitability of the system" (9:7). The goal being to measure ". . . the system against the operational criteria outlined in program documentation developed by DOD, HQ USAF, and operating and supporting commands (for example, system operational concepts)" (9:3). From these operational criteria test objectives are developed.

DEVELOPMENT OF TEST OBJECTIVES

The development of OT&E objectives is best viewed as an analytical process. The process is presented graphically in Figure 1. This figure is a composition of those found in Air Force Regulation 55-43 and AFOTEC Pamphlet 400-1. OT&E objectives flow from the original documents requesting or documenting a need for a new weapon system.

The original source document usually is the "Statement of Operational Need" or SON. It is in this document that an Air Force agency identifies what it needs to fulfill current mission requirements or must have to fulfill a new mission in the future. The SON should, "... express capabilities which the new system is expected to achieve" (5:11). It is from these requirements and capabilities that critical issues are developed.

"Critical issues are those aspects addressing a system's essential capabilities, risks, or uncertainties that must be explained before the systems overall worth can be estimated" (7:14). Simply, critical issues address the question, "Can we do what we need to do with the proposed system?" For the purpose of OT&E, critical issues addressing operational issues are identified and separately labeled as "critical operational issues" and used to develop OT&E objectives.

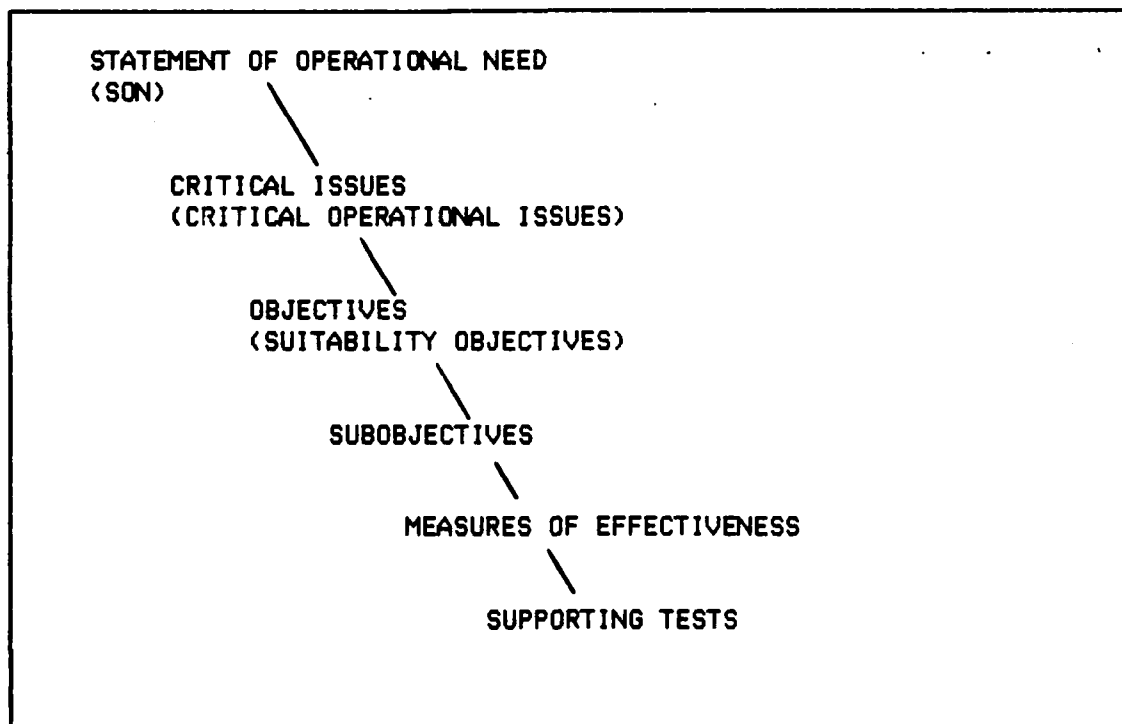


Figure 1. Flow Diagram of Test and Evaluation Process (5:13; 7:18).

OT&E objectives form the foundation for operational test and evaluation. "Objectives address the scope of OT&E, the critical issues, and ultimately determine the resources required" (7:19). Hence, the objectives flow from the critical operational issues. Test objectives usually address characteristics of the system and are related to the critical issues (7:19; 5:14). Subobjectives may be needed to further breakdown the objective into quantitative, measurable units addressing specific system characteristics. (7:19; 5:14) The sub-objectives form the building blocks that support an objective, which in turn, supports a critical issue.

General guidance on the development of objectives and sub-objectives is provided in AFR 55-43, Management of OT&E. A checklist is provided for the planner to compare objectives and subobjectives. More specific guidance on actual development of operational suitability test objectives is found in AFOTTECP 400-1, Logistics Assessment. This document stresses the identification and separation of critical issues relating to suitability and the development of OT&E objectives and sub-objectives. (5:39)

Measures of effectiveness (MOEs) form the link between test objectives and tests. "An MOE is a quantitative or qualitative measure of a system's performance or characteristic which indicates the degree to which it performs a task or meets an objective under specified conditions" (7:22). An MOE is related to a specific test objective. As example, an MOE may specify the mean time between maintenance (MTBM) (5:14). The MOEs flow from the list of functions the system is to perform. These MOEs are then tied to specific test events (7:22). AFOTTECP 400-1 (5:14) states, "Test planning depends on developing MOEs that are directly applicable to the test objectives."

DEVELOPMENT OF SUPPORTING TESTS

Major General Patrick Powers of the Army Test and Evaluation Command gave a perspective on the importance of tests when he stated, "One good test is worth a thousand expert opinions and usually costs less" (16:35). Tests are developed to support the OT&E objectives, and result from an analysis of the missions the weapon system is going to be required to perform. AFR 55-43 provides guidance for the development of supporting tests.

The greatest emphasis in the current test guidance is that they are as realistic and representative of the actual operating environment as possible. (9:3; 7:16; 5:30) But, the guidance also recognizes the limitations in conducting realistic tests. (7:16; 5:30) A quote from AFR 55-43 typifies this. "To fulfill the need for operational realism, a test scenario should approximate the intended operations environment within the constraints imposed by safety considerations, fiscal resources, the natural environment, and time allotted to OT&E" (7:16).

The guidance on test development in AFR 55-43 relates mainly to operational effectiveness tests. The process described is general in nature. All missions the system is to perform are listed and further broken down into various mission elements and the specific actions and tasks in each mission element. These tasks are then prioritized and considered against the objectives and program constraints. (7:77-78)

The corresponding section under suitability test approach in AFR 55-43 provides no guidance on how to develop supporting suitability tests nor does it state the necessity for supporting tests. It suggests using simulations and modeling because of limitations and undeveloped logistic support system (7:81).

In the literature concerning OT&E tests, the same emphasis on realism can be found (2:224-225; 14:22; 17:48; 12:91; 15:4). However, there is not the emphasis on testing limitations. General Powers believes testing will save time and money in the future and calls for more testing, not less. He also thinks testing should not suffer due to scheduling or time constraints (16:158).

The literature does point out some additional considerations for suitability test planners. Rear Admiral Kollmorgen, Assistant Director, Strategic and Support Systems Test and Evaluation, Office of Research and Engineering, points out the dependence on laboratory and bench testing for reliability evaluation which fails to expose equipment and systems to operational stress and operational personnel. He also states the need to expose hardware to the cumulative effects of the operational environment (13:9). Major General Leaf, former Commander of the Air Force Test and Evaluation Center, also stated the need for testing to be ". . . conducted by the operations and maintenance personnel who will use the system in the field." (14:21) Karns also states the need for testing utilizing operational personnel (12:91). General Leaf also recognized the need for separate OT&E tests and that eventually DT&E tests must yield to operational tests (14:22-23).

As testified above, experts agree that tests to support operational suitability should be as realistic as possible, utilize operational personnel, and be conducted in the operational environment. The test should be dedicated to OT&E, separate from DT&E tests, and within the limitations of the program and other constraints.

DEVELOPMENT OF EVALUATION METHODOLOGIES

Once supporting tests have been conducted and the results of the tests collected, these results must be evaluated. Lieutenant Colonel Robbins (17:51) stated in a 1974 article:

Tests alone do not provide simple answers totally applicable to operational reality. Evaluation is needed to apply reasoning and judgement to the test results and answer the operational questions about a weapon system's effectiveness and suitability (17:51).

Specific guidance is provided in AFOTTECP 400-1, Logistics Assessment, on the suitability evaluation methodologies. The pamphlet addresses common techniques to evaluate suitability objectives. A brief synopsis of each follows.

Availability

The assessment of availability determines if the system is operable and committable when needed at a random point in time. Availability is a function of reliability, maintainability, and logistics supportability. It is usually expressed as the percentage of assets committable when called upon to perform the required mission. Availability can be mathematically expressed as:

$$\text{Availability} = \frac{\text{Hours committable}}{\text{Total hours possessed}}$$

The general approach to evaluate availability is to collect data on how often the system breaks (reliability), how long it takes to fix (maintainability), and how responsive support equipment, technical data, facilities, and supply support are when a demand is placed on them (logistics supportability).

The guidance on availability points out that assessment of availability during IOT&E may be difficult due to lack of operational equipment and tests in an operational environment. The recommended actions to assist in the evaluation of availability is to use modeling or simulation (5:Ch 16, A7-1 - A7-2).

Reliability

The assessment of reliability determines the frequency a system will fail when operated. Quantitatively, it can be expressed as a probability the system will work for the time required to perform its intended mission. It can also be expressed as mean time between maintenance (MTBM), mean time between removal (MTBR), or mean time between critical failure (MTBCF). Other measures can be used, but these are the most common. Data requirements to evaluate system reliability

are failures, operating hours, maintenance events, and other events that render the system inoperable (5:Ch 17, A7-4 - A7-6).

Reliability evaluation and estimates during IOT&E may be difficult because of low operating hours. Additionally, point estimates during IOT&E only indicate current reliability and do not project reliability of the mature system. Therefore, the reliability evaluation and estimates must include reliability growth techniques to reliably represent future projections (5:141). Because of limited operating hours during IOT&E tests of hardware, evaluation estimates should also take into consideration hours of operation accumulated during representative DT&E tests (12:91; 13:8).

Maintainability

The assessment and evaluation of maintainability is to determine if the system can be sustained in an operational state within a given level of support. Maintainability can be evaluated both quantitatively and qualitatively. Quantitatively, the system can be evaluated by looking at the average time a system is not capable of performing its intended mission (mean downtime (MDT)). Other quantitative measures of maintainability include the maintenance manhours required to repair the system and the average time to repair or restore the system, mean time to repair (MTTR). Qualitatively, maintainability of the system should be evaluated for accessibility, serviceability, ease of maintenance, safety, and human factors.

Sources of data for maintainability evaluation are repair time on failures, number of personnel performing tasks, questions and comments of evaluators and technicians, and other data collected for availability and reliability evaluations. As with reliability, maintainability may experience growth and the evaluation should include a growth program to project mature estimates of maintainability (5:Ch 18, A7-7 - A7-9).

Logistics Supportability

"Logistics supportability assessment addresses the various elements of integrated logistics support (ILS). . . ." (5:48). The specific areas usually addressed as part of logistics supportability include support equipment, technical data, transportation, packaging and handling techniques, facilities, and supply support. The evaluation of this area seeks to determine if the demands on the logistics system are reasonable and can be met by the proposed support system. A brief description of evaluation methodology for each of the above areas follows.

Support equipment. Individual pieces of support equipment may be given the same level of evaluation as major sub-systems of the overall weapon system. Considerations such as availability, reliability, and maintainability of the equipment should be evaluated. Sources for data are the same as those stated under methodologies for availability, reliability, and maintainability for the major weapon system (5:48-50).

Technical data. The evaluation of technical data determines accuracy, completeness, and usability by the technicians who will be required to use it when the system is fielded. Much of the data for evaluation should come from hands-on use of the technical data by evaluators and technicians. Documentation of errors and changes provides evaluation information. The evaluation of technical data tends to be a very subjective and qualitative assessment (5:53-55).

Packaging, handling, and transportation. Evaluation of packaging, handling and transportation is conducted to ensure the system, sub-systems, and support items can be safely and securely moved. "Such areas as protection from weather and rough handling are prime considerations" (5:55). When assessing packaging, handling, and transportation, evaluators should consider all damaged shipments and review applicable procedures for handling and transportation of equipment. This area of evaluation is also subjective, but can be supported quantitatively through documentation of equipment damaged during shipping or handling (5:55-57).

Facilities. New weapons systems may require new or modified facilities to support the system. The adequacy of these facilities should be evaluated to ensure they meet the needs of the maintenance and operational personnel. Also, if additional facilities are required the deficiency should be identified. Results of other measured areas, such as reliability and maintainability, can provide evaluation data for the facilities evaluation. Evaluation of facilities is more qualitative than quantitative (5:57-58).

Supply support. Spares, new and repaired, are essential to maintain any system in a high operational state. Evaluation of the supply support for a new system determines how well the system is designed and planned to support the demands of the weapon system. Data to evaluate supply support comes from reliability data, which shows demands on the system, and planned provisioning information. High failure rate items should be identified, as well as items requiring additional monitoring or evaluation (5:50-53).

Supply support and all the other areas of logistics supportability are difficult to evaluate during IOT&E because of the early equipment designs and lack of operational equipment. The total integrated logistics support system is seldom complete. Therefore, evaluation of this area requires many subjective judgements and utilization of projections, contractor estimates, and data from other evaluation areas.

Chapter Three

DESCRIPTION AND ANALYSIS OF SUITABILITY TEST OBJECTIVES, SUPPORTING TESTS, AND EVALUATION METHODOLOGIES OF THE PEACEKEEPER IN MINUTEMAN SILOS TEST PROGRAM

The planned objectives, tests, and evaluation methodologies are drawn from two sources. They are the Peacekeeper Operational Test and Evaluation Plan and the Integrated Test Plan for the Peacekeeper in Minuteman Silos Weapon System. The flow of the test objectives from the critical issues is shown graphically in Figure 2 and described narratively. The development of supporting tests and their relationship to the test objectives is described. And finally the evaluation methodologies as described in the test plan are presented along with additional information on the evaluation methodologies.

TEST OBJECTIVES

Description

There were five critical operational issues identified for the Peacekeeper program. Only two of those issues which provide the starting point for the suitability test objectives will be discussed. The first of these critical issues is:

Mission Effectiveness. the Peacekeeper missile force must be: capable of being effectively targeted against candidate targets, available for operational commitments, and if executed, successfully complete assigned mission profiles. This capability is best described by a factor called mission effectiveness which measures the percentage of deployed warheads that, if executed, would produce a detonation in intended target areas discounting the effects of enemy action. It is therefore vital for the Peacekeeper missile system to achieve a sufficient level of mission effectiveness. The areas which must be addressed in support of the mission effectiveness factor are targeting efficiency, alert availability (SAC operational readiness rate), and launch and flight reliability (3:2-2).

The second critical issue is:

Weapon system operation and support. The weapon system must be capable of being operated, maintained, and logistically supported throughout its [sic] life cycle. This issue encompassed logistics reliability, maintainability, support equipment, transportation and handling, technical data, supply support, manpower and training (3:2-3).

As shown in Figure 2 four of the operational suitability objectives flow from these two critical operational issues.

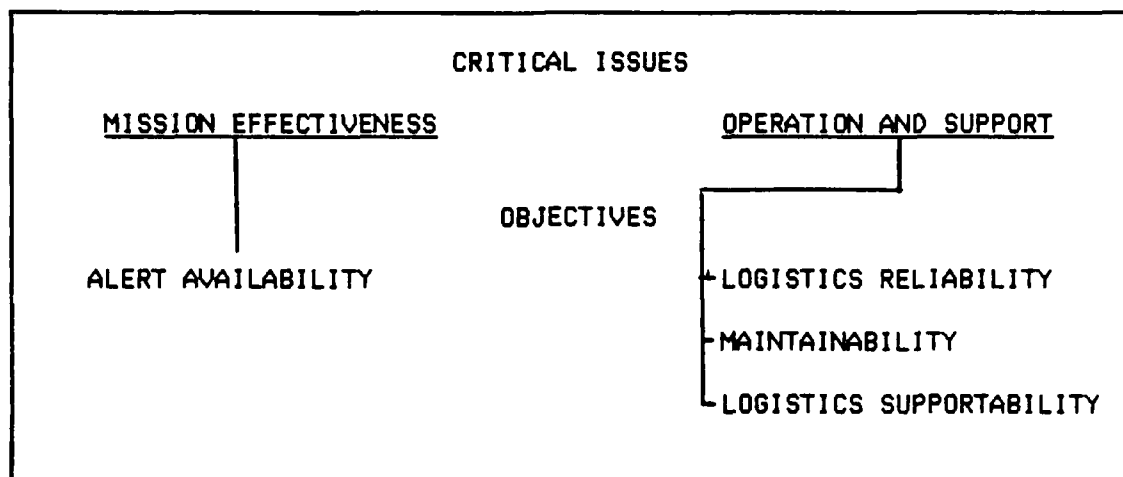


Figure 2. Flow Diagram of PIMS Test Objectives.

The first of the initial operational suitability test objectives is to "Estimate the alert availability of the Peacekeeper weapon system" (3:B-2). This factor seeks to determine the probability a missile will be available when needed. The mathematical expression given for availability in the test plan (3:B-2) is:

$$\text{Peacekeeper Alert Availability (100 missiles)} = \frac{\text{Total System Hours} - \text{Total Hours Off Alert}}{\text{Total System Hours}}$$

Total hours off alert refers to the total time the system is not capable of being launched. These hours are a result of the findings and estimates of the reliability, maintainability, and logistics supportability objectives (3:B-2).

The second suitability objective is: "Evaluate the logistics reliability of the Peacekeeper weapon system" (3:B-5). The goal of this objective is "... to characterize the maintenance and repair

requirements associated with the new Peacekeeper missile and other equipment changes to make it operate in a Minuteman launch facility" (3:B-7). Assessment of the maintenance workload and demands on the logistics support system is the primary output of this objective. These results are then to be compared with projected support requirements and the differences identified (3:B-9).

The third suitability objective is "Evaluate the maintainability of the Peacekeeper weapon system" (3:B-11). The objective determines the "maintenance and repair timelines" to support the weapon system. (3:B-11) These maintenance and repair timelines are to be compared with current Minuteman maintainability factors and predicted maintenance factors to look for differences.

The fourth objective is logistics supportability and it has five subobjectives (3:B-14). They are:

1. Evaluate the adequacy of the support equipment.
2. Evaluate the transportation, packaging, and handling techniques.
3. Evaluate the adequacy of technical data.
4. Evaluate the adequacy of facilities.
5. Evaluate the supply support.

This objective determines, through the five sub-objectives, the supportability of the weapon system in the operational environment. For the Peacekeeper program each subobjective is evaluated at two levels; individually and then for its overall impact on weapon system availability (3:B-14).

Evaluation of Peacekeeper support equipment focuses on those pieces of equipment that "troubleshoot, test, calibrate, and repair" the system and other equipment to maintain the system (3:B-15). Emphasis is placed on the qualitative aspects of the support equipment rather than the quantitative measures. This is shown in the test plan, for example, ". . . MSE [maintenance support equipment] should be mobile, easily handled, standardized . . ." (3:B-15).

Because of the long distances between support bases and remote missile launch facilities, evaluation of transportation, packaging, and handling techniques is important. The goal of this objective is to determine if equipment and systems can be transported and handled safely, without damaging those systems and equipment. Another consideration for this objective is the manhours required to transport and handle the equipment. The primary emphasis of this objective is evaluation of procedures for transportation and handling between the support base and the launch facility (3:B-16 - B-18).

The evaluation of technical data will ". . . examine technical data as a vital element of the Peacekeeper weapon system that affects virtually every interaction between operator/maintainer and equipment" (3:B-18). The technical data will be judged based on it's ability to

meet "... command requirements and operational concepts" (3:B-20). Additionally, the technical data should be usable and understandable by the using technicians. The test plan provides a list of other criteria to evaluate technical data for usability by individuals (3:B-19).

New and modified facilities are being built to support the Peacekeeper weapon system. The subobjective to evaluate the adequacy of facilities seeks to determine if the new facilities can

... safely and efficiently (timely completion) support all missile processing tasks, missile maintenance activities, and missile emplacement sequence to return a Peacekeeper facility to alert status following a missile/component recycle requirement (3:B-21).

The objective also concerns itself with the safety and working conditions of the personnel utilizing the facility. Any deficiencies in the facilities are identified, especially those that impact the availability of the entire weapon system (3:B-21).

Evaluation of the Peacekeeper supply support looks at the supply levels and the failure rates to see if differences exist. This subobjective of logistics supportability is closely related to the two major objectives of logistics reliability and availability. If a component fails (reliability) and spares are not available to replace the failed component, the weapons system will not be able to accomplish its mission (availability). The test plan points out that the evaluation of supply support is an ongoing and an "iterative process" because of the "dynamic" relationship between failure rates and spare parts levels (3:B-22 - B-23).

Analysis

The PIMS test objectives followed the development procedure outlined in Air Force regulations. The critical operational issues were identified and then supporting test objectives developed. The test objectives for the initial operational suitability evaluation were the classic suitability objectives of availability, reliability, maintainability, and logistics supportability. However, with the exception of the logistics supportability objective, none of the other objectives had supporting subobjectives. Further, specific MOEs were not developed for any of the four major suitability test objectives. The failure to develop subobjectives and specific MOEs may have led to the small number of supporting tests for operational suitability.

SUPPORTING TESTS

Description

The PIMS test program recognized the relationship between test objectives and supporting tests, but also realized the limitations in testing as shown by the following statements. "A major activity in the OT&E process is the establishment of test requirements which define how testing must be accomplished to meet all test objectives" (3:2-5). "Because of the limited and expensive test assets, the destructive nature of ICBM flight tests, and compressed schedule between major milestones and IOC [Initial Operational Capability], the Peacekeeper test and evaluation effort is a combined DT&E/OT&E program" (3:21). However, the operational test planners made a decision to place emphasis on tests supporting the operational effectiveness test objectives over suitability objectives (3:2-6).

Tests to support the IOT&E suitability test objectives are found in the "Weapon System Testing" section of the Integrated Test Plan (ITP). "Peacekeeper weapon system tests are conducted on operationally representative equipment and facilities to demonstrate system compliance with operational requirements" (6:1-6). Within the weapon system tests, 44 tests support the four suitability test objectives of availability, reliability, maintainability, and logistics supportability. Many of the tests more than one of the objective. There are 11 tests tied to availability, one test tied to logistics reliability, 41 tests tied to maintainability, and 32 tests tied to logistics supportability. The flight tests support operational suitability objectives, but they are not shown as supporting the objectives in the ITP. The majority of the tests tied to the suitability objectives are tests to evaluate the performance of maintenance tasks and the maintainability objective.

The ITP also plans for the involvement of the IOT&E test team in the testing. "The primary purpose for AFOTEC participation is to satisfy OT&E objectives and requirements" (6:1-51). Test team involvement will gradually increase from "observation to involvement to performance" (6:1-53). The performance of the maintenance and operations tasks shifting from contractors to Air Force personnel provides a more realistic operational environment for testing (6:1-51 - 1-53).

Analysis

The emphasis on the tests supporting operational suitability objectives is directed at the maintainability objective. Forty-one of the 44 tests tied to the suitability objectives are tests in which maintenance tasks are performed. The few remaining tests support technical data or measure the operational suitability for operations personnel versus maintenance tasks.

In reviewing the tests and the objectives they are tied to, some relationships are questionable. It appears that rather than the tests

being developed to support test objectives, tests were developed and then tied to an objective it might support. An example is the logistics reliability objective and the single test tied to the objective. The test is an evaluation of the Expanded Maintenance Data Acquisition System (EMDAS), a data collection system already in place at Minuteman bases. The system is used to collect fault information and maintenance responses and will eventually be used by the Peacekeeper weapon system. The EMDAS system has no effect on the reliability of the Peacekeeper weapon system. It is also unusual that the flight tests are not shown as supporting the logistics reliability objective, when in fact these tests provided the primary source of operationally relevant failure data for the logistics reliability assessment.

The test planners did have the foresight to call for the involvement of Air Force personnel to perform tasks in the operational environment, utilizing operational hardware and procedures. The ITP shows the plan for this involvement through a very specific participation matrix detailing how, when, and to what degree Air Force test personnel would participate (6:1-54 - 1-56). One test also shows the attempt to expose the weapon system and associated hardware to the varied operational environments. This adverse weather test measures the performance of maintenance in cold weather, and satisfies the need for making the tests as operationally relevant as possible.

The test plan (3:1-10) also outlines the gradual shift in test emphasis from DT&E to OT&E. AFR 80-14 and DOD Directive 5000.3 state, "Any combined test program chosen shall contain enough dedicated operational test events to satisfy the operational testing agency requirements for an independent evaluation" (9:24; 10:8). The final phase of testing and test flights were planned for operational testing and the emphasis placed on OT&E tests. However to date, the final three test flights have not taken place.

In conclusion, tests to support all operational suitability objectives are not present in the plan. The tests that were included, however, were well designed in that they emphasized operationally realistic environments, used operational hardware and procedures, and were performed by the people required to operate them the system when deployed.

EVALUATION METHODOLOGIES

The evaluation methodologies utilized by the PIMS test program were not necessarily in line with those recommended by the current guidance. One reason for this may have been the lack of supporting tests and MOEs tying tests to objectives. The availability model in the test plan provides one of the more specific methodologies presented.

Description of Alert Availability

Estimation of Peacekeeper alert availability requires examination of the three factors affecting it. The first factor is the reason the system will be unable to launch and fulfill its intended mission. Component failure is a primary factor affecting alert availability. Other reasons preventing launch commitment are periodic maintenance, tests, and owning command requirements. The second factor affecting availability is how long it takes to restore the system when it is not launch capable. This factor includes actual repair times, travel times, and any other factors that may delay restoring the weapon system. The third factor is support items influencing availability. Areas examined in this factor include ". . . manpower, tools, vehicles, and spares . . ." (3:B-4). The source of data for the assessment of availability comes from contractor predictions, current Minuteman maintenance and reliability data, and the results of the other three suitability objectives of reliability, maintainability, and logistics supportability. The results of the objectives and other assessments are placed into a model, which is shown in Figure 3. The final output of the availability objective is an estimate of alert availability. This estimate is then compared to the using command's required availability (3:B-3 - B-5).

Analysis of Availability

The guidance for evaluation of availability clearly recognizes the difficulty in evaluating availability and recommends the use of modeling or simulation (5:Ch 16, A7-1 - A7-2). While the PIMS planners recognized the limitations in collecting data to support the availability analysis, no simulation or modeling was planned nor was it ever used. Also, the planners did not use standard, acceptable terms or methods in the availability model. For example, they chose to use "number of annual occurrences" rather than mean time between replacement (MTBR) or mean time between maintenance (MTBM) and "time to restore" instead of using the standard term of mean downtime (MDT). The estimate produced by the model is the same, but it is not a straight forward method.

Description of Logistics Reliability

Evaluation of logistics reliability involves examining what each contractor says his system will do and measuring this against what it actually does during testing. The evaluators look for discrepancies between what is predicted and what is observed. These differences are reported and used to revise predictions that characterize system failure. Emphasis is placed on using the Logistics Support Analysis Record (LSAR) as the source and reporting document. Actual failure data is collected by the test team and used for analysis. Other outputs of this objective are used to determine high failure rate items, safety concerns, and high manhour consuming items. These are then converted into yearly occurrences for inclusion in the availability model (Figure 3) (3:B-5 - B-11).

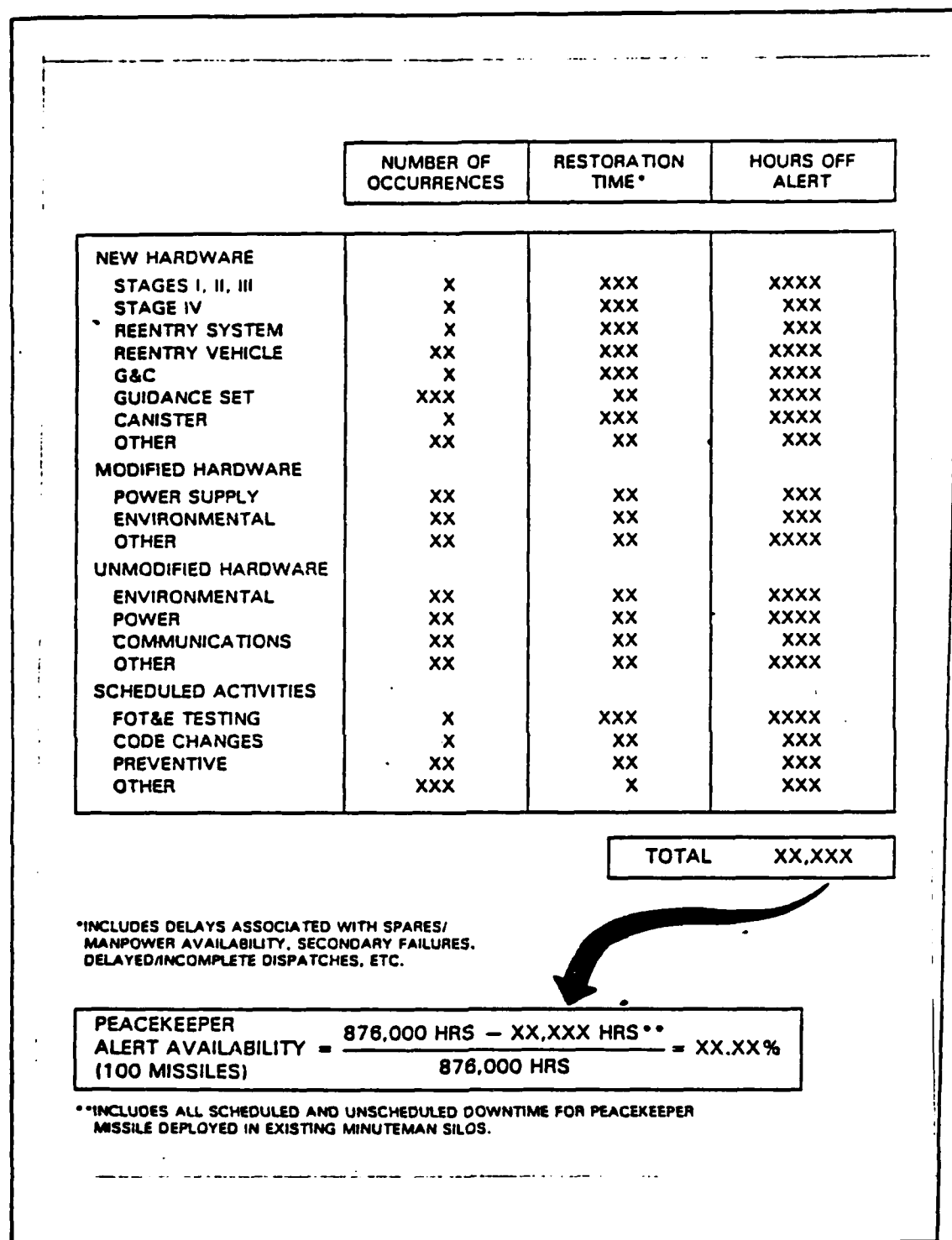


Figure 3. An Example of Predictive Off-Alert Model (3:B-6).

Analysis of Logistics Reliability

The evaluation of the weapon system's logistics reliability is again not necessarily within the guidance provided. There were no specific MOEs and no specific tests to support this objective. Evaluation relied largely on contractor provided evaluations and data. Related to this dependence on contractor data was the fact that the PIMS program did not have a centralized data collection system as required by the guidance. A limited data collection system was developed by the test team but did not include inputs from any other sources. Much of the data used to evaluate the logistics reliability of the system came from operation of the system prior to a flight test. These periods were relatively short (an average of seven days) when compared to the continuous run requirements of the operational system. Also, no use of reliability growth techniques was incorporated in the test plan. The use of reliability growth techniques is recommended in the current guidance (5:141) and would have been appropriate because of the high operating time requirements and the low number of actual hours during testing.

Description of Maintainability

As with reliability, maintainability is assessed by examining what each contractor estimates the maintenance requirements are, compared to what is observed by the test team. This objective is supported by 41 tests of which the majority are the actual performance of maintenance tasks by test team personnel. Differences between the contractor predictions and actual performance are reported. The sources of data are contractor reports, the LSAR, and actual performance data collected by the test team. The evaluation looks for high manpower consuming tasks, tasks taking a long time to perform, and methods to improve and shorten tasks. Also, timelines are developed to input into the availability model as time to restore the system. These timelines include all applicable travel times, delays, and maintenance actions (3:B-11 - B-14).

Analysis of Maintainability

The maintainability objective is well supported by actual tests. The evaluation provides data to make a quantitative assessment of the weapon system's maintainability and also allows a qualitative evaluation by Air Force personnel performing the tests. However, no specific MOEs were established for this objective to link the tests and the major objective. Standard maintainability terms, such as MDT and MTTR were not used in the description of the methodology. As with logistics reliability, no maintainability growth techniques were planned for or used by the test team.

Description of Logistics Supportability

Each of the five subobjectives of the logistics supportability objective has a separate methodology in the test plan. The first sub-

objective of support equipment takes a limited approach to the evaluation. No specific tests were developed to support this evaluation, but rather evaluation takes place only when the equipment is actually needed due to a failure or planned task. Much of the analysis will be accomplished by design reviews and "table-top" reviews of support equipment procedures. Sources for data come from contractors' designs, performance data, and test team observations. Support equipment affecting availability is highlighted for further study and analysis, and subjective, qualitative assessments of support equipment are also made (3:B-14 - B-16).

The methodology to evaluate transportation, packaging, and handling is supported by specific tests of the operational procedures used to handle and transport major components of the weapon system. Test team members perform transportation and handling tasks, report any problems, and record actual times to perform the tasks for comparison with predicted contractor times. Additionally, the evaluation makes a qualitative assessment of the transportation, packaging, and handling procedures (3:B-16 - B-18).

The method used to evaluate technical data is taken from operators and technicians using the technical data to prepare missiles for the flight test program. If operational technical data is not yet available for use, the test team will participate in technical order reviews, validations, and verifications (3:B-18 - B-20). The evaluation compares the technical data to the "... using command requirements and operational concept" (3:B-20).

While no specific test is dedicated to the facilities sub-objective, many of the maintenance tasks must be performed in the new or modified facilities at both the operational base and the test base. The test team also participates in facility design reviews to assess their adequacy in meeting operational needs (3:B-20 - B-21).

To evaluate supply support, actual failure rates of the components are compared to the projected supply levels. If, based on the failure rates, a shortfall exists in the supply levels, it is reported. Shortfalls in the supply levels can impact the availability of the weapon system, so any shortfall may require further study. Because of this, the test plan calls for an ongoing evaluation of supply support (3:B-22 - B-23).

Analysis of Logistics Supportability

The logistics supportability objective had supporting tests which provided data for evaluation. Also, the numerous maintainability test events, requiring use of the maintenance support equipment, supported the evaluation of the support equipment. The test plan methodology does not establish any requirements to measure availability, reliability, or maintainability of the maintenance support equipment; however, since it impacts availability it was done by the evaluators conducting the evaluation of the support equipment. Technical data was supported in

much the same way as support equipment. Air Force technicians performing the maintenance and operations tasks used the operational technical data. They were able to make a qualitative assessment of the technical data and recommend changes. The areas evaluated were in line with those outlined in the current guidance. The packaging, handling, and transportation of the Peacekeeper weapon system was supported by tests of the system. The tests measured how well the procedures protected the system from damage and the elements. The criteria used to evaluate the procedures were in accordance with the current guidance. Again, as with support equipment and technical data, the numerous maintenance tests supported the evaluation of the new and modified Peacekeeper facilities. The methodology to evaluate supply support is in accordance with the guidance; however, because of its close relationship with the major objective of logistics reliability, the evaluation of this sub-objective is affected. If the logistics reliability objectives does not provide adequate, accurate data, the supply support objective will probably not be adequate or accurate.

CONCLUSION

The overall methodology to evaluate operational suitability is characterized by a dependence on maintainability tests and too few tests to support the logistics reliability objective. This results in over dependence on subjective evaluations. The lack of reliability and maintainability growth techniques also detracts, and is in conflict with current guidance. "Testing shall be planned and conducted to provide quantitative data and to minimize the need for subjective interpretations of system performance" (9:2-3).

Chapter Four

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Shortcomings in the current guidance prevent optimum conduct of initial operational suitability test and evaluation of land based ICBMs. As pointed out in the recommendations, guidance specifically designed to develop suitability MOEs is needed to provide the link between objectives and tests. The most serious shortcoming is the lack of emphasis and guidance to develop tests to support suitability objectives. With today's increased emphasis on reliability and maintainability, realistic suitability testing is essential for all weapon systems. Simulation and modeling are helpful, but require too many assumptions and subjective evaluations. Evaluation methodologies designed for land based ICBMs are needed. Current specific guidance available in AFOTTECP 400-1, is inadequate as it does not provide guidance for ICBMs. An ICBM annex is required for this directive.

When compared with the guidance available, the PIMS test program was hampered by the lack of guidance. In some cases, the test planners did not follow the guidance available. Whether this was deliberate or not cannot be determined by this author and is outside the limits of this study. The failure to utilize any kind of simulation or modeling or reliability growth techniques¹ are two of the more notable exceptions to the guidance. There was no centralized data collection system in the PIMS program and the guidance is very specific in the need for a centralized data collection system. This made evaluation of logistics reliability and maintainability difficult for the operational test team. Other factors such as the compressed schedule, cost, indecision on basing, and Presidential and Congressional interest drove the test program.

Future ICBM IOT&E testing will become even more complicated than the PeaceKeeper program because of the requirement for new mobile launch platforms. PeaceKeeper Rail Garrison and the Small ICBM are both mobile systems. The suitability testing for these systems presents the test planner with new challenges for developing test objectives, supporting tests, and evaluation methodologies to ensure the Air Force receives reliable and maintainable weapon systems.

¹ Reliability growth technique was employed for the Missile Guidance and Control Set (MGCS).

RECOMMENDATIONS

Suitability Test Objectives

The analytical process to develop suitability objectives from the critical operational issues provides an adequate means to develop test objectives, as the major suitability objectives are standard for virtually any weapon system. The area requiring additional guidance for ICBM test objectives is MOEs. ICBM missions are not varied; their challenge is in maintaining a constant state of readiness. The MOE process outlined in the guidance is more oriented to aircraft type "mission effectiveness" rather than ICBM slanted "suitability." Overall, the guidance to develop test objectives is sufficient for any weapon system, including ICBMs, but lacking in the development of ICBM MOEs to tie objectives to tests.

Supporting Tests

The emphasis in the current guidance is on the development of mission effectiveness tests and evaluations. AFR 55-43 provides a process to develop tests supporting mission effectiveness but the corresponding section under suitability test development does not provide any process. Its only recommendation is to use simulation and modeling. This omission appears to affect not only tests to support ICBM suitability testing but other systems as well. Guidance to develop tests to support suitability test objectives should be expanded to be at least as detailed as those for mission effectiveness. Also, in considering tests to support ICBM suitability testing, the guidance should consider the operation of ICBMs and the requirements for extended system running times and maintenance demands.

Evaluation Methodologies

AFOTECF 400-1 Logistics Assessment, provides detailed descriptions of each of the suitability objectives and methodologies to evaluate the objectives of availability, reliability, maintainability and logistics supportability. However, the only reference to missiles is in an appendix for "munitions and missiles" referring to missiles used with aircraft. There is no corresponding appendix for land-based ICBMs. An appendix for land based ICBMs is needed to support suitability evaluation methods of these systems.

Other

The current process of test and evaluation is very dependent on the requirements established by the Air Force agency requesting the new system. While researching the current guidance, a new Air Force Pamphlet was found which should have an impact on testing to determine operational suitability. AFP 57-9, Defining Logistics Requirements in

Statements of Operational Need, has the following purpose:

The best opportunity for influencing design, from a readiness and logistics perspective, is at the front end (preconceptual and conceptual phases) of the acquisition process. The most effective is by establishing specific, realistic qualitative and quantitative readiness and logistics requirements in the SON (10:1).

This pamphlet also has specific guidance for strategic land based ICBMs logistics requirements such as a measure for maintenance manhours per operational unit, mean down time, mean time to repair, and mean time between maintenance (10:18). The recognition that ICBMs require separate consideration and should not be considered with munitions or aircraft is a step in the right direction.

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APPENDIX

APPENDIX A

Definitions

Definitions of key terms are presented so the reader will have an understanding of the terminology used in this paper. Definitions presented here are standard definitions used throughout the Air Force and Department of Defense and are taken from representative regulations. Where definitions are broader than the scope of this paper, those definitions are so annotated.

Availability. A measure of the degree to which an item is in the operable and committable state when the mission is called for at any random point in time. Availability is dependent on reliability, maintainability, and logistics supportability.

(ICBM Availability) The percent of a missile force capable of commitment to the launch sequence at any random point in time. (5:A2-3)

Critical Issues. Those aspects of a system's capability, either operational, technical, or other, that must be questioned before a system's overall worth can be estimated, and that are of primary importance to the decision authority in reaching a decision to allow the system to advance into the next acquisition phase. (9:34)

Initial Operational Test and Evaluation (IOT&E). The first phase of operational test and evaluation conducted on preproduction, prototypes, or pilot production items and normally completed prior to the first major production decision. It is conducted to provide a valid estimate of a system's operational effectiveness and operational suitability prior to the first major production decision. (9:35)

Logistics Supportability. How well the composite of support considerations necessary to achieve the effective and economical support of a system or equipment for its life cycle meets stated quantitative and qualitative requirements. This includes integrated logistics support and logistics related O&S cost considerations. (5:A2-11)

Maintainability. The measure of the ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. (5:A2-11)

Operational Suitability. The degree to which a system can be satisfactorily place in field use with consideration being given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistic supportability, and training requirements. (9:36)

NOTE: For consideration in this paper operational suitability is limited to availability, logistics reliability, maintainability, and

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logistics supportability. Those areas that do not overlap into effectiveness. (5:5)

Operational Test and Evaluation (OT&E). OT&E is conducted in as realistic conditions as possible throughout the system life cycle. It is done to estimate (or to refine estimates of) a system's operational effectiveness and operational suitability, to identify any operational deficiencies, and to identify the need for any modifications. (5:A2-15)

Reliability. The probability that an item will perform its intended function for a specified interval under stated conditions. (Logistics Reliability) A measure of a system's capability to operate as planned under the defined operational and support concepts using specified logistics resources (for example, spares or manpower). Logistics reliability recognizes the effect of all occurrences that place a demand on the logistics support system even when mission capability is unaffected. (5:A2-17)

Test and Evaluation. The term "test" denotes any project or program designed to obtain, verify, and provide data for the evaluation of research and development other than laboratory experiments; Progress in accomplishing development objectives; performance and operational capability of system, subsystems, components; and equipment items. The term "evaluation" denotes the review and analysis of quantitative data produced during current or previous testing, data obtained from test conducted by other government agencies and contractors, from operation and commercial experience, or combinations thereof. (5:A2-19)

APPENDIX

APPENDIX B

Abbreviations and Acronyms

A

AFOTEC	Air Force Operational Test and Evaluation Center
AFOTEC P	AFOTEC Pamphlet
AFP	Air Force Pamphlet
AFR	Air Force Regulation

D

DOD	Department of Defense
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E

EMDAS	Expanded Minuteman data analysis system
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F

FOT&E	Follow-on operational test and evaluation
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I

ICBM	Intercontinental ballistic missile
IOT&E	Initial operational test and evaluation
ITP	Integrated test plan

L

LSAR	Logistics support analysis record
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M

MDT	Mean downtime
MOE	Measure of effectiveness
MSE	Maintenance support equipment
MTBF	Mean time between failure
MTBCF	Mean time between critical failure
MTTR	Mean time between replacement
MTBM	Mean time between maintenance

O

OT&E	Operational test and evaluation
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P

PIMS	Peacekeeper in Minuteman silos
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Statement of Operational Need

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